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U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

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TRANSMITTAL LETTER TO THE UNITED STATES
DESIGNATED/ELECTED OFFICE (DO/EO/US)
CONCERNING A FILING UNDER 35 U.S.C. 371

705/72338-2

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.5)

09/509466

INTERNATIONAL APPLICATION NO.

PCT/SE98/01735

INTERNATIONAL FILING DATE

29 September 1998

PRIORITY DATE CLAIMED

30 September 1997

TITLE OF INVENTION

ROTATING ELECTRIC MACHINE WITH MAGNETIC CIRCUIT

APPLICANT(S) FOR DO/EO/US

Bengt ROTHMAN

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(1).
4. ☐ A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
 - a. ☒ is transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ has been transmitted by the International Bureau.
 - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ A translation of the International Application into English (35 U.S.C. 371(c)(2)).
7. ☐ A copy of the International Search Report (PCT/ISA/210).
8. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
 - a. ☐ are transmitted herewith (required only if not transmitted by the International Bureau).
 - b. ☐ have been transmitted by the International Bureau.
 - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
 - d. ☐ have not been made and will not be made.
9. ☐ A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
10. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☐ A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 13 to 18 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
A **SECOND** or **SUBSEQUENT** preliminary amendment.
16. ☐ A substitute specification.
17. ☐ A change of power of attorney and/or address letter.
18. ☐ Certificate of Mailing by Express Mail
19. ☐ Other items or information:

09509466

Page 2 of 2

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:)	PATENT
)	
Bengt ROTHMAN)	Group: To Be Assigned
)	
Serial No: New Application)	Examiner: To Be Assigned
Based on PCT/SE98/01735)	
)	
Filed: March 28, 2000)	
)	
ROTATING ELECTRIC MACHINE)	
WITH MAGNETIC CIRCUIT)	

PRELIMINARY AMENDMENT

March 28, 2000

Commissioner of Patents
and Trademarks
Washington, D.C. 20231

Sir:

Prior to initial examination merits, please amend the above-identified application as follows:

IN THE CLAIMS:

Please amend the claims as follows:

1. (Amended) A rotating electric machine having a magnetic circuit for high voltage, [characterized by] wherein a stator [(11) the] having a winding [of] which comprises a high-voltage cable [(1)], and a rotor [(9)] surrounding the stator [(11)], the cable [(1)] comprising a flexible conductor surrounded by solid insulation having an inner layer with semiconducting properties, an insulating part and an outer layer with semiconducting properties.

2. (Amended) [A] The device as claimed in claim 1, [characterized in that]

3. (Amended) [A] The machine as claimed in claim 1, [or 2, characterized in

4. (Amended) [A] The machine as claimed in claim 3, [characterized in that]

5. (Amended) [A] The machine as claimed in claim 3, [characterized in that]

6. (Amended) [A] The machine as claimed in claim 4 [or 5, characterized in

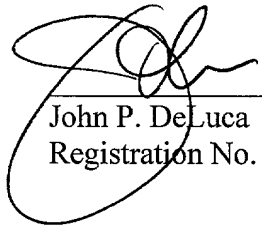
7. (Amended) [A] The machine as claimed in [any of claims 1-6, characterized

REMARKS

Applicant has amended the claims in order to delete the multiple dependencies from and to place them in better U.S. format. In the event that any multiple dependencies remain in the claims, it is respectfully requested that said multiple dependencies be deleted and reference be made to the immediately preceding claim.

Examination on the merits is earnestly solicited.

Respectfully submitted,



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ROTATING ELECTRIC MACHINE WITH MAGNETIC CIRCUIT

The rotating electric machines referred to herein comprise synchronous machines used primarily as generators for connection to distribution and transmission networks, in the following referred to as power networks. The synchronous machines are also used as motors as well as for phase compensation and voltage control and in that case as mechanically open-circuited machines. The technical field also includes dual-fed machines, asynchronous static current converter cascades, outerpole machines and synchronous flow machines. These machines are intended for use with high voltages. High voltages shall be understood here to mean electric voltages in excess of 10 kV. A typical operating range for the machine according to the invention may be 36 to 800 kV.

The use of high-voltage insulated electric conductors in the stator winding, the conductors in the following being termed cables, with solid insulation similar to that used in cables for transmitting electric power (e.g. PEX cables), enables the voltage of the machine to be increased to such levels that it can be connected directly to the power network without an intermediate transformer. The need for fast, continuously adjustable reactive power is thus satisfied, connected directly to subtransmission or transmission level in order to deal with system stability and/or the dependence of rotating mass and e.m.f. in the vicinity of high-voltage direct current transmissions or, alternatively, to generate or consume high-voltage alternating current connected directly to subtransmission or transmission level. The station may be for a few MVA up to thousands of MVA.

The obvious advantage is that transformers in which the reactance consumes reactive power are unnecessary, as are also traditional high-power circuit breakers. Advantages are also gained with regard to network quality since rotating compensation is obtained, and with regard to overload capacity which may be +100% in such machines. The control range may be +100% for reactive power.

However, problems may arise since the stator winding in such a high-voltage machine, with cable of the type described, acquires considerable radial dimension. At a given diameter of the machine's air gap, the diameter increases in proportion to the number of turns of the winding and

the slots in the stator laminations carrying the cable must be deep and the stator laminations numerous.

The object of the present invention is to solve the above-mentioned problems and provide a machine with a smaller stator and thus an arrangement which is smaller in dimension but not in power. This object is achieved by the machine according to the invention being given the characteristics defined in the claims.

The invention will be described in more detail with reference to the accompanying drawings, in which

- 10 Figure 1 shows a cross section through a cable used in the invention,
Figure 2 shows an axial section through a machine according to the invention, designed as a hydroelectric generator,
Figure 3 likewise shows an axial section through a second embodiment of the machine according to the invention,
15 Figure 4 likewise shows an axial section through a third embodiment of the invention according to the invention, and
Figure 5 likewise shows an axial section through a fourth embodiment of the invention according to the invention.

20 The invention is in the first place intended for use with a high-voltage cable 1 of the type (Fig. 1) built up of a core having a plurality of strand parts 2, an insulating layer 4 surrounding the inner semiconducting layer, and an outer semiconducting layer 5, and its advantages are particularly pronounced here. The invention refers particularly to such a cable
25 having a diameter within the interval 20-200 mm and a conducting area within the interval 80-3000 mm². The cable therefore does not include the outer sheath that normally surrounds a cable for power distribution.

The insulated conductor or high-voltage cable used in the present invention is flexible and is of the type described in more detail in
30 WO 97/45919 and WO 97/45847. The insulated conductor or cable is described further in WO 97/45918, WO 97/45930 and WO 97/45931.

Accordingly, the windings, in the arrangement according to the invention, are preferably of a type corresponding to cables having solid, extruded insulation, of a type now used for power distribution, such as
35 XLPE-cables or cables with EPR-insulation. Such a cable comprises an inner conductor composed of one or more strand parts, an inner semicon-

ducting layer surrounding the conductor, a solid insulating layer surrounding this and an outer semiconducting layer surrounding the insulating layer. Such cables are flexible, which is an important property in this context since the technology for the arrangement according to the invention is based primarily on winding systems in which the winding is formed from cable which is bent during assembly. The flexibility of an XLPE-cable normally corresponds to a radius of curvature of approximately 20 cm for a cable with a diameter of 30 mm, and a radius of curvature of approximately 65 cm for a cable with a diameter of 80 mm. In the present application the term "flexible" is used to indicate that the winding is flexible down to a radius of curvature in the order of four times the cable diameter, preferably eight to twelve times the cable diameter.

The winding should be constructed to retain its properties even when it is bent and when it is subjected to thermal or mechanical stress during operation. It is vital that the layers retain their adhesion to each other in this context. The material properties of the layers are decisive here, particularly their elasticity and relative coefficients of thermal expansion. In an XLPE-cable, for instance, the insulating layer consists of cross-linked, low-density polyethylene, and the semiconducting layers consist of polyethylene with soot and metal particles mixed in. Changes in volume as a result of temperature fluctuations are completely absorbed as changes in radius in the cable and, thanks to the comparatively slight difference between the coefficients of thermal expansion in the layers in relation to the elasticity of these materials, the radial expansion can take place without the adhesion between the layers being lost.

The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having resistivity within the range of 10^{-1} - 10^6 ohm-cm, e.g. 1-500 ohm-cm, or 10-200 ohm-cm, naturally also fall within the scope of the invention.

The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentene ("TPX"), cross-linked materials such as cross-linked polyethylene

(XLPE), or rubber such as ethylene propylene rubber (EPR) or silicon rubber.

5 The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention.

10 The insulating layer and the semiconducting layers thus have substantially the same coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber (EVA/NBR), butyl graft polyethylene, ethylene-butyl-acrylate copolymers (EBA) and ethylene-ethyl-acrylate copolymers (EEA) may also constitute suitable polymers for the semiconducting layers.

15

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with the combination of the materials listed above.

20 The materials listed above have relatively good elasticity, with an E-modulus of $E < 500$ MPa, preferably < 200 MPa. The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction of the elasticity so that no cracks appear, or any other damage, and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as in the weakest of the materials.

25

The conductivity of the two semiconducting layers is sufficient to substantially equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently high to enclose the electrical field within the cable, but sufficiently low not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

30

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

35

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

In Figure 1, illustrating the insulated conductor or cable, the three layers are executed so that they adhere to each other even when the cable is bent. The cable shown is flexible and this property is retained throughout the life of the cable.

Figure 2 shows in axial section a first embodiment of a rotating high-voltage machine according to the invention, in this case in the form of a hydroelectric generator. The rotor spokes 8 are attached on the turbine shaft 6 which, in this case, is journaled in a single guide bearing 7. These spokes support the rotor 9 with its excitation winding 10. The stator 11 is supported from below on a fixed foundation 12, and coil ends 14 of the stator winding 13 protrude from the stator 11.

In comparison with high-voltage machines proposed earlier, thus, the stator and rotor have exchanged places on each side of the air gap 15. This means that the slot depth 16 for the stator winding 13 will be smaller, and also the number of stator laminations will be fewer for a given air gap diameter 17.

18 denotes brakes for the rotor 9, arranged on the fixed foundation 12 for friction engagement with the rotor. The arrows in Figure 2 indicate the flow of cooling air through the stator 11.

The poles 21 on the rotor are pronounced and since they are placed on the inside of the rotor 9, against the stator 11, the rotor ring can be run at high speed without risk of problems with regard to its strength as may otherwise be the case in the higher speed register.

Figures 3-5 show three other embodiments of the machine according to the invention, designed as a hydroelectric generator. These figures reveal various ways of utilizing the generator pit 22 with varying degrees of success. Figure 3 shows the stator 11 suspended from the fixed beam 19, while the rotor 9 is supported by spokes 8 arranged below the stator. In this case, however, two guide bearings 7 and 20 are required for the shaft 6.

Figure 4 shows a embodiment of the machine in which, as in Figure 3, the rotor spokes 8 are arranged below the stator 11. The generator pit 22 is utilized better and the total height is less since the spokes 8 are

inclined slightly upwards. However, two guide bearings 7 and 20 are still required.

Figure 5 shows an even more compressed embodiment with the spokes 8 still further inclined. The machine has thus been compressed to such an extent that one guide bearing 7 is sufficient.

The rotor 9 and stator 11 may be so dimensioned that at nominal voltage, nominal power factor and over-excited operation, the thermally based stator and rotor current limits are exceeded approximately simultaneously. However, they may also be dimensioned so that at nominal voltage, nominal power factor and over-excited operation, the thermally based stator limit is exceeded before the thermally based rotor current limit is exceeded. At nominal voltage, nominal power factor and over-excited operation, the machine preferably has 100% overload capacity for two hours. The synchronous reactance in transverse direction is suitably considerably less than the synchronous reactance in direct direction. The machine is suitably equipped with excitation systems enabling negative and positive excitation.

The stator-winding phases in the machine are preferably Y-connected. The Y-point of the stator winding can then be insulated and protected from over-voltages by surge diverters. However, the Y-point of the stator winding may be earthed with the aid of a third-harmonic filter, i.e. a suppression filter between Y-point and earth. The suppression filter may be so designed that it greatly reduces or even eliminates third-harmonic currents through the machine, while at the same time being dimensioned so that voltages and currents are limited in the event of faults in the system. The third-harmonic filter may be protected against over-voltages by surge diverters connected in parallel with the third-harmonic filter.

CLAIMS

1. A rotating electric machine having a magnetic circuit for high voltage, characterized by a stator (11) the winding of which comprises a high-voltage cable (1), and a rotor (9) surrounding the stator (11), the cable (1) comprising a flexible conductor surrounded by solid insulation having an inner layer with semiconducting properties, an insulating part and an outer layer with semiconducting properties.
2. A device as claimed in claim 1, characterized in that the layers are arranged to adhere to each other even when the cable is bent.
3. A machine as claimed in claim 1 or claim 2, characterized in that the rotor (9) is rigidly connected to the machine shaft (6) for out-going or in-going kinetic energy via spokes (17) extending past the stator (11).
4. A machine as claimed in claim 3, characterized in that the stator (11) is supported from below on a fixed foundation (12) and in that the rotor (9) is supported from above by spokes (8) extending over the stator (11) from the machine shaft (6).
5. A machine as claimed in claim 3, characterized in that the stator (11) is supported from above by fixed radial beams (19) and in that the rotor (9) is supported from below by spokes (8) extending below the stator (11) from the machine shaft (6).
6. A machine as claimed in claim 4 or claim 5, characterized in that the brakes (18) for the rotor are arranged on the fixed foundation (12) for friction engagement with the rotor (9).
7. A machine as claimed in any of claims 1-6, characterized in that the rotor (9) has pronounced poles (21).

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Fig. 1

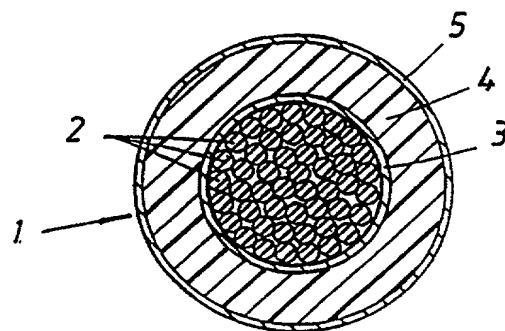
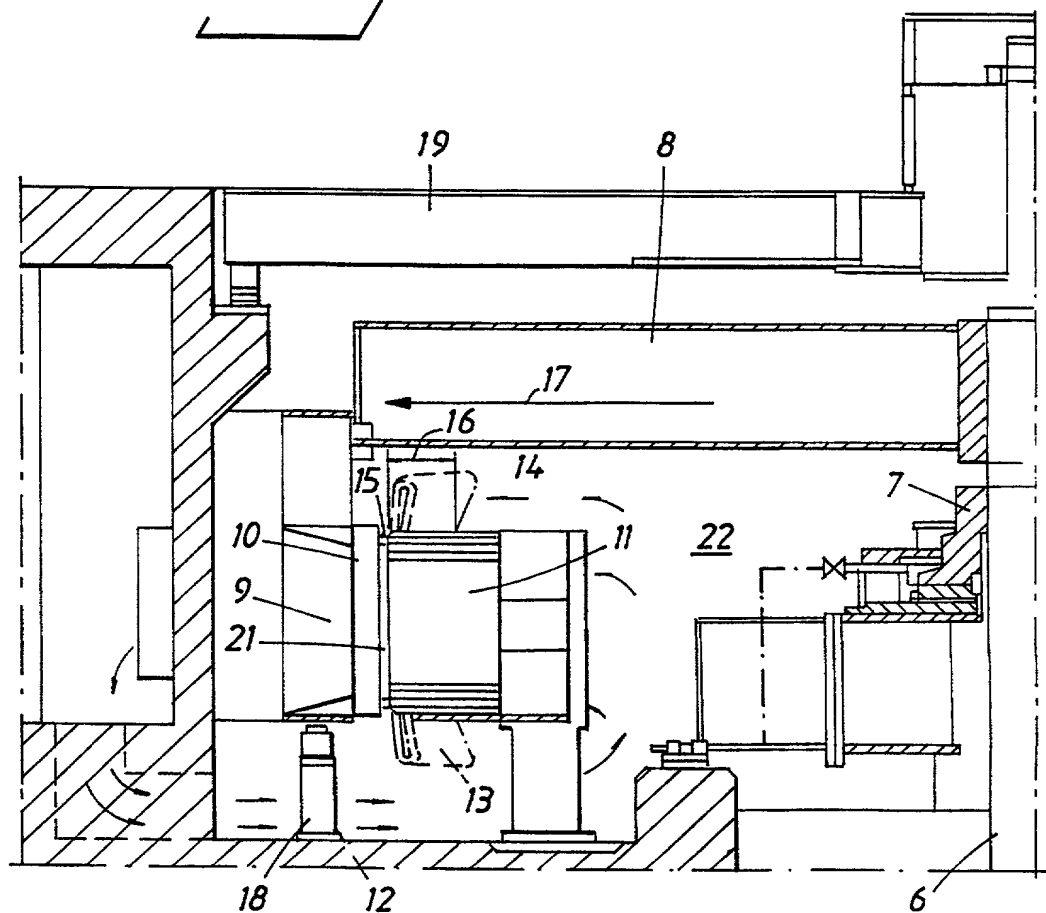
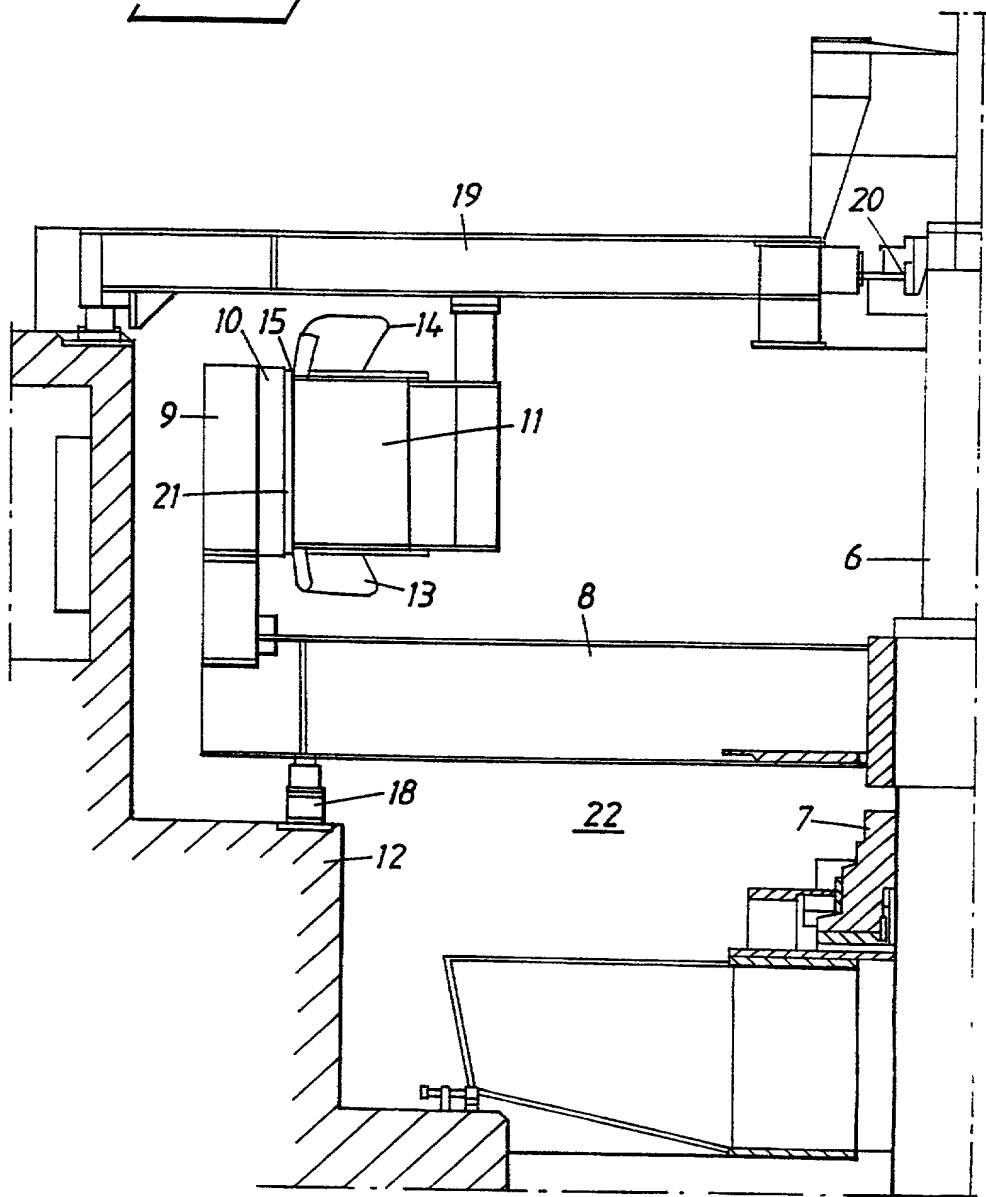


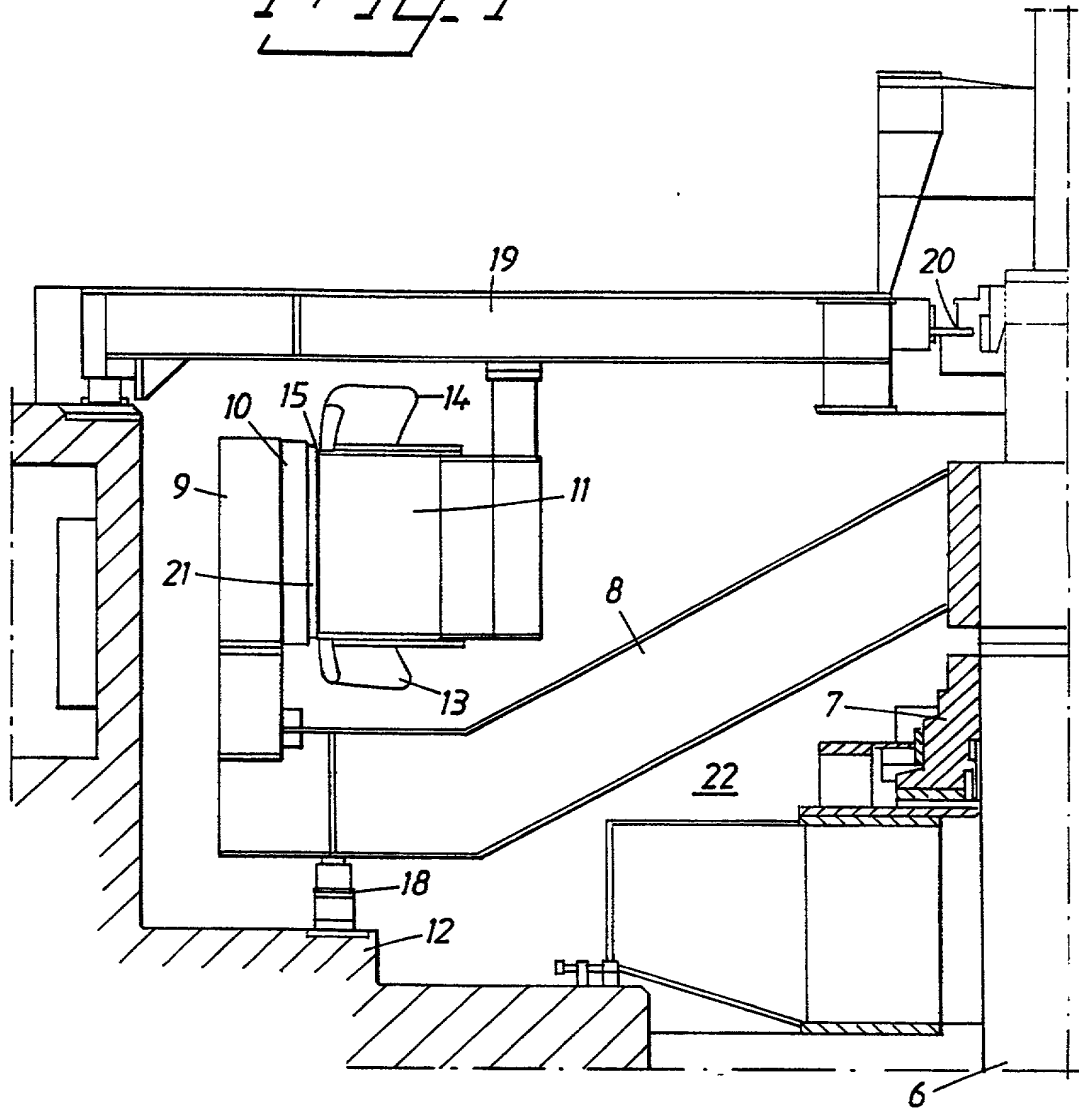
Fig. 2





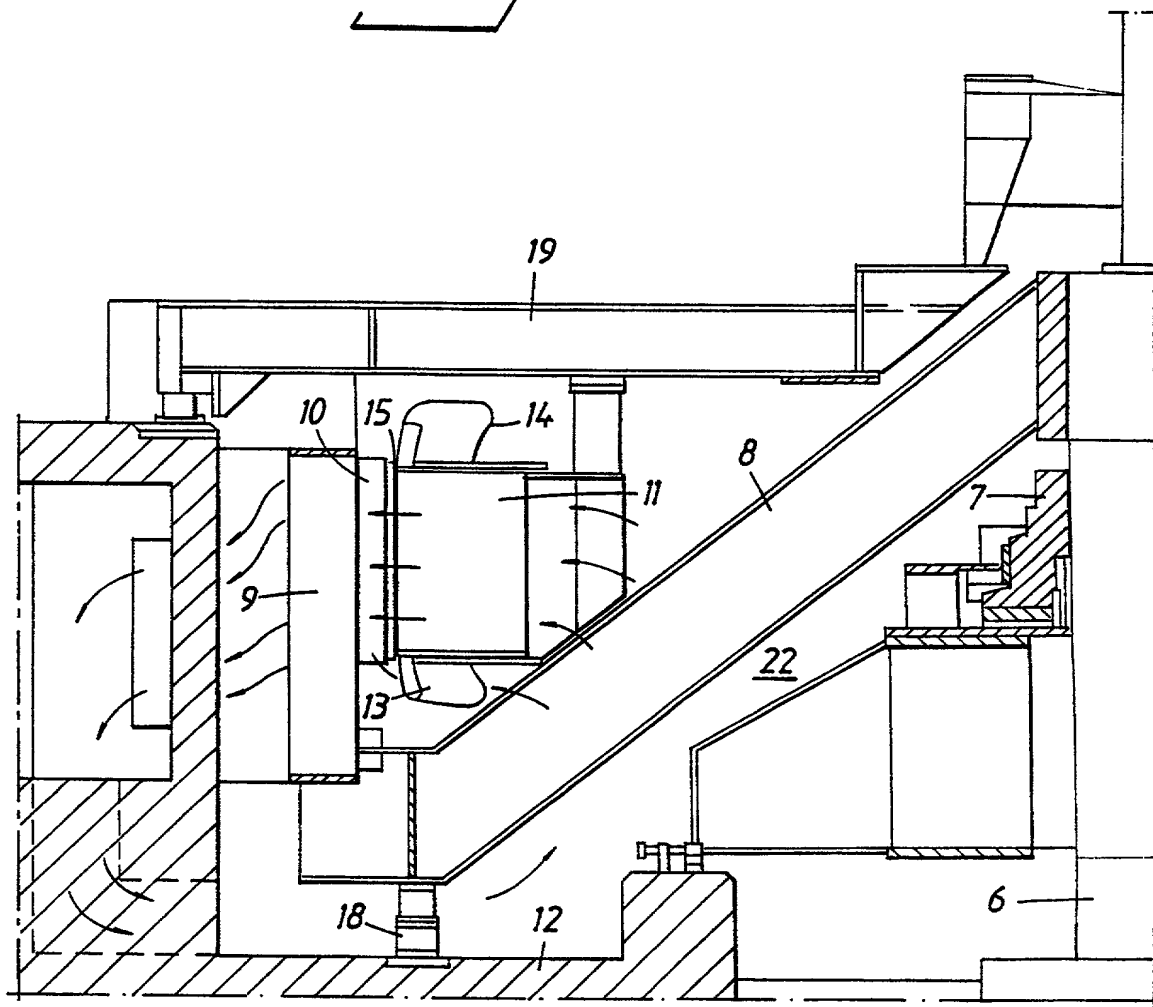
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Fig. 4



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Fig. 5



Attorney Docket No.
705/72338-2

My residence, post office address and citizenship are as stated below next to my name; that

the specification of which (check one): ☐ is attached hereto.

[X] was filed as PCT international application no. PCT/SE98/01735 on 29 September 1998, and was amended under PCT Article 19 on _____ (if applicable).

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I do not know and do not believe the claimed invention was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months prior to this application.

I hereby claim foreign priority benefits under Title 35, United States Code §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application(s) on which priority is claimed:

Prior Foreign Application(s)

Priority Claimed

9703549-7	Sweden	30 September 1997	<input checked="" type="checkbox"/>	<input type="checkbox"/>
(Number)	(Country)	Day/Month/Year Filed	Yes	No
			<input type="checkbox"/>	<input type="checkbox"/>
(Number)	(Country)	Day/Month/Year Filed	Yes	No

I hereby claim the benefit under Title 35, United States Code, §119 (e) of any United States provisional application(s) listed below:

Application No.	Day/Month/Year Filed	Application No.	Day/Month/Year Filed
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[illegible]

Status (patented, pending, abandoned)

Status (patented, pending, abandoned)

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Same As Above